SALSA
Speeds Solutions for Water-Scarce Southwest

PEGGY GREB (K9960-1)

Hydraulic engineer David Goodrich examines cottonwood leaves for signs of water stress in the San Pedro Riparian National Conservation Area.

It's been called "a ribbon of life," "a miracle of the desert," and "one of the last great places."

The Upper San Pedro River Basin of southeastern Arizona is perhaps best known for its astounding variety of bird life. Some are seldom-seen species like the azure bluebird, green kingfisher, and American bittern. Others are more familiar, like the red-tailed hawk. Ornithologists estimate that anywhere from 1 to 4 million birds visit the basin on their way to or from their summer breeding and nesting grounds.

The cottonwood forests and willow thickets that line the banks of the San Pedro make a perfect place for these birds to feed and rest. Too, this unique region also hosts an impressive array of other wildlife, including blacktail prairie dogs, gray foxes, and piglike javelinas.

Roughly 130 miles long, the San Pedro River extends from the state of Sonora in northern Mexico into Arizona, finally disappearing into the Gila River about 50 miles north of Tucson, Arizona. Along the way, the river cuts through oak savannas, desert scrub, and grassland expanses.

In the Upper San Pedro Basin, the river is fed in part by a vast aquifer. Experts estimate that this porous underground layer of sand, clay, and fractured rock holds some 13 trillion gallons of water.

A Budget Out of Balance

The aquifer is relatively easy and inexpensive to pump. In fact, it is the sole source of water for rural and city residents in the basin and the Fort Huachuca military base. But there is a problem with the aquifer. "Currently, the amount of water that's being removed is more than that replaced by rainfall and seepage," explains David C. Goodrich. He is a hydraulic engineer with ARS' Southwest Watershed Research Center in Tucson.

The most recent estimates set this water debt at about 2.4 billion gallons a year. This not-inconsequential deficit is one telling indicator of an ecosystem in trouble. "Even with the tremendous amount of water in the aquifer," Goodrich points out, "the river flow will eventually be reduced if the debt continues." The demand for water—to meet the needs of people, plants, and animals—is unlikely to decrease, he says.

"Sufficient water is really the key issue in the Upper San Pedro," Goodrich emphasizes. "Having enough for the river habitat—and all the species it supports—and enough water for current and future residents of the basin for rural, municipal, domestic, agricultural, industrial, and military use is critical."

Investigations by researchers such as Goodrich may lead to new and better ways to meet the needs of users and, at the same time, move closer to balancing the basin's water budget. To this end, Goodrich and colleagues at the Tucson laboratory began an intensive, international effort to scrutinize the hydrology and ecology of the river and its basin on both sides of the border.

ARS is the lead scientific agency in this venture, which includes nine federal agencies, eight universities, six foreign agencies, and four private organizations. Known as the Semi-Arid Land-Surface-Atmosphere research program, or SALSA for short, the collaboration is now in its sixth year. SALSA findings might apply to other major watersheds throughout the United States. Some examples: the Rio Grande Basin spanning Colorado, New Mexico, Texas, and northern Mexico; and the lower Colorado Basin in Arizona, Nevada, and California.

A spin-off effort, called SUD-Med, was launched in 2001 to focus on several basins near Marrakech in Morocco. In all, Goodrich notes, the SALSA and SUD-Med discoveries will likely be applicable to much of the planet's semiarid and arid lands.

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Plant physiologist Chandra Holifield separates grass samples used to validate the SEHEM plant-growth model.

How Much Water Do Riverbank Trees Really Drink?

The intent of SALSA is to produce science-based ways to predict the effect that various natural or human changes might have on the water balance and the plant and animal life in the basin. Plants play a key role in cycling water through the basin, taking moisture up through their roots, then giving it off as water vapor through leaves, stems, and trunks.

"Everyone knows that plants like cottonwoods take up and use a lot of water," says Goodrich. "Even so, it would help if we knew how much." Until now, the best anyone could come up with was a very rough estimate of the monthly or yearly water needs of plants like cottonwood or willow.

To solve this problem, Goodrich and co-investigators created some high-tech approaches to measure and predict the amount of water riverside plants require. They used scanner laser beams to measure the amount of water the plants gave off, sap-flow sensors to detect the quantity traveling through tree trunks, and naturally occurring atomic tracers to identify the trees' water sources.

In addition, they relied on devices called scintillometers to track the amount of heat radiated from the ground and vegetation. They also used satellite-mounted sensors called radiometers to determine the amount, type, and temperature of the vegetation.

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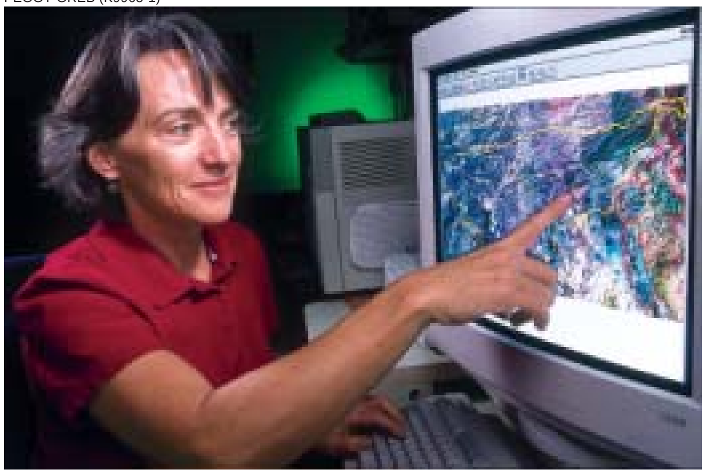


Hydrologist Susan Moran assesses the condition of grassland from an image produced by a satellite sensor.

"As far as we know," says Goodrich, "these are the first direct estimates of how much water these riparian plants really use." The team's preliminary results indicate that plants draw up about 15 percent less water than was generally thought to be the case. That figure is significant enough "to make a real difference in choosing among management strategies," Goodrich says.

Grasslands Also Garner Attention

About one-third of the San Pedro Basin is covered with hardy grasses like blue grama, sideoats grama, and sacaton grass. These rugged plants make ideal cover for mice, rabbits, and other creatures that are, in turn, prey for the region's raptors—owls, hawks, falcons, and eagles.

On both sides of the U.S.-Mexico border, beef cattle graze this rangeland mix of grasses and desert shrubs throughout the year. Ranchers have to be careful not to put too many cattle on these ranges because overgrazing can lead to erosion. What's more, the loss of plant cover can hasten the rush of floodwaters, which, in turn, can damage river channels and lessen the quality of river water.

Perhaps surprisingly, the size and condition of the grasses' roots is one of the most telling indicators of the health of the rangeland—and a good predictor of the plants' future growth. ARS research leader and hydrologist M. Susan Moran at Tucson and Yann Nouvellon, formerly a NASA-sponsored postdoctoral researcher at Moran's laboratory, have developed a mathematical model that will, among other things, give ranchers a good indication of whether a stand of grass has strong, healthy roots. "It's somewhat like knowing if your front lawn has a good root system," Moran explains. "If it does, you know it is more likely to green up after a rain."

Similarly, if they have good information about the size and condition of roots, ranchers should be able to use the model to estimate how Southwest desert grasses will respond to the region's typical summer monsoon and winter rains.

SEHEM for Savvy Management

Moran and Nouvellon have dubbed their model SEHEM, short for Spatially Explicit Hydro-Ecological Model. It's based on mathematical formulas that can be run on an ordinary desktop computer. When data about the grasses and the weather are plugged into the formulas, the computer can generate customized color maps that ranchers can use to estimate where, and how much, forage might be available for hungry cattle to graze in the coming months.

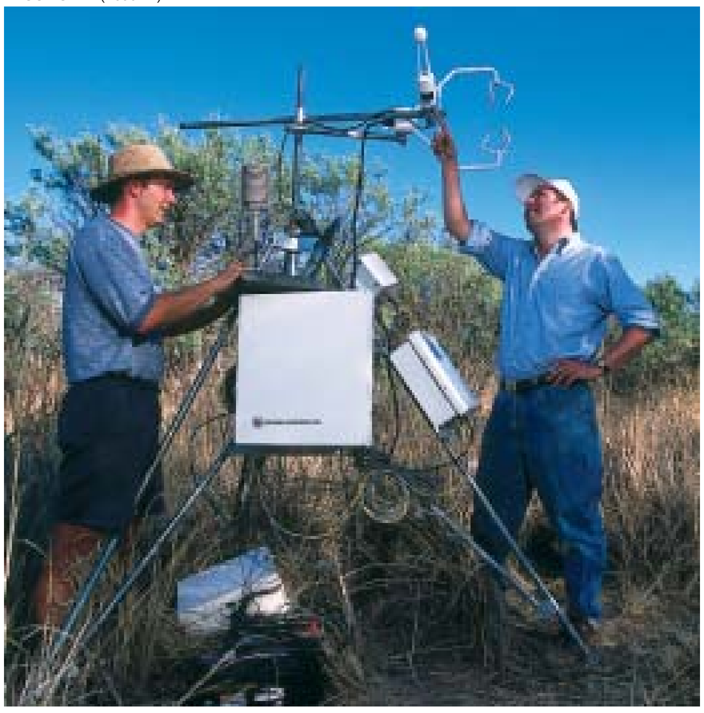
To create a model like this basically required taking known facts about how these wildland grasses grow, as well as data about weather, and then converting that information into a numerical form that a computer can process and analyze. Computer models that simulate weather or how a plant might grow above and below ground, given certain typical weather patterns, aren't new. So what's new about SEHEM? Likely the broad expanse of land for which SEHEM has so far proven accurate and reliable.

Moran and Nouvellon tested the model using weather data from a solitary, self-operating meteorological station. They meshed it with data from the huge swaths viewed by satellite-mounted sensors. The information from the meteorological station was very accurate for a small, localized part of the basin where the station was located. This 10-foot-high tower, loaded with weather instruments, is situated at the ARS Walnut Gulch Experimental Watershed, near Tombstone, about 175 miles southeast of Phoenix.

"We have 12 years' worth of detailed weather information from the station," Moran notes. "But it's very localized. If you were to try to extrapolate it to predict grass growth over a much broader area, like someone's 10,000-acre ranch, you might lose a significant amount of accuracy—unless you had the help of SEHEM.

"The satellite imagery from NASA's LANDSAT Thematic Mapper and LANDSAT Enhanced TM Plus," she says, "covers the exact same site as our Walnut Gulch meteorological station and more than 12,000 square miles, as well. But this satellite imagery of plants, soil, and other natural features is at a much different scale and a much less-frequent time interval—just 29 images for an entire 10-year period."

PEGGY GREB (K9961-1)



Rick Edwards (left), University of Arizona graduate student, and David Goodrich download data from a meteorology/flux system, which measures the amount of water and carbon exchanged among vegetation, soil, and atmosphere.

Next Target: Great Basin

"The SEHEM model we developed allows us to use both of these important data sets," Moran explains. "With its scope and specificity, SEHEM should be appropriate for broad areas." Moran says that puts the researchers in the ballpark for having the scale and degree of accuracy to make the model a practical, workable tool for the region's ranchers, conservationists, and others interested in safeguarding the desert grasslands.

Moran and Nouvellon validated the model by having it project plant growth for specific periods—in the past—for which they already had accurate information about the vegetation. Says Moran, "We already knew about aboveground growth, but we wanted to see whether the model could accurately predict the same thing. The correlation was quite good, and we've been able to make adjustments in the equations to fine-tune or calibrate them."

This procedure made SEHEM one of the first validated models for predicting growth of rangeland grasses over a very broad area. The scientists are using the same approach—teaming up single-point, very-long-term meteorological data with infrequently obtained, high-resolution satellite imagery—for other regions. In particular, they're doing that to develop a new model specifically for predicting growth of wildland grasses in the Great Basin ranges of Utah, Nevada, and parts of Idaho. In the meantime, Moran expects SEHEM to "go a long way toward helping prevent the overgrazing that occurred on some San Pedro Basin grasslands in the past."

For their studies, Goodrich, Moran, and 67 other SALSA team members have won a USDA honor award for environmental protection. SALSA scientists have reported their findings in *Agricultural and Forest Meteorology, Remote Sensing of Environment, Water Resources Research,* and other scientific publications. Two CDs, available from Goodrich at no charge while supplies last, tell more about SALSA. They are "Miracle of a Desert River" and "San Pedro River Basin Spatial Data Archive."—By **Marcia Wood,** ARS.

This research is part of Water Quality and Management, an ARS National Program (#201) described on the World Wide Web at http://www.nps.ars.usda.gov.

David C. Goodrich and M. Susan Moran are with the USDA-ARS Southwest Watershed Research Center, 2000 E. Allen Rd., Tucson, AZ 85719; phone (520) 670-6380, fax (520) 670-5550, e-mail dgoodrich@tucson.ars.ag.gov, smoran@tucson.ars.ag.gov. ◆

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